VISUAL REPRESENTATION OF MATERIAL STIFFNESS AND STRESS-STRAIN BEHAVIOR IN GEOMECHANICS MODELING

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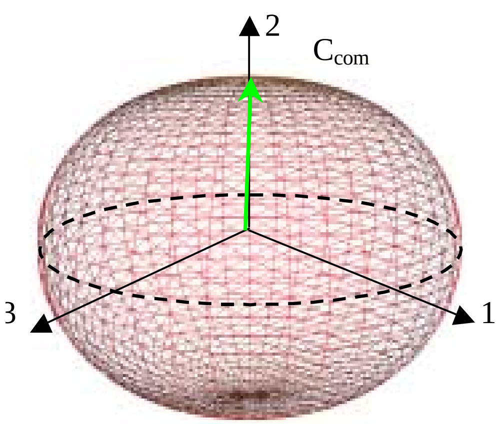
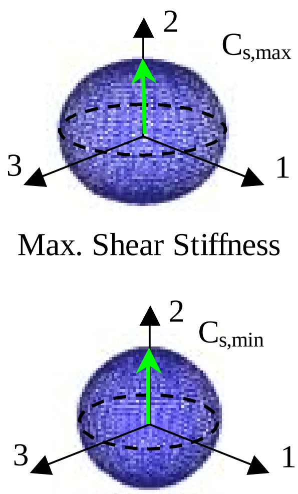
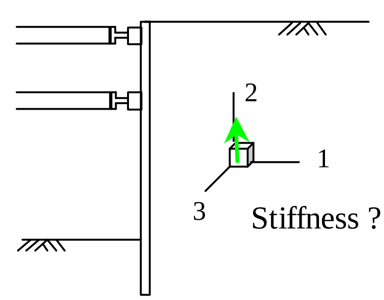
There has been significant effort to visualize the state of stress or strain at a point, however due to various difficulties little has been done to visualize the material stiffness. It is therefore very difficult to answer questions related to the implied soil stiffness from highly non-linear soil models. It is not possible to adequately quantify the stiffness of the soil at a given construction stage in a numerical analysis. A systematic method is needed to explore the stiffness response of a constitutive model in such a way as to provide results that are meaningful. The purpose of this paper is to present a visualization tool to represent the entire fourth order stiffness tensor as a geometric object(s) to aid in the understanding of the complex stiffness of a constitutive model, especially as it is used in boundary-value problems.

A visualization technique is introduced where for all possible directions originating from a point, three separate stiffness surfaces can be generated which represent the compressive, and minimum, and maximum shear stiffness of the soil. The minimum shear stiffness will be of particular interest in geotechnical analysis. The figure below shows the visual objects for a cross anisotropic soil (plane of isotropy is the 1-3 plane). The origin of the objects is the point of interest. The intersection of a vector oriented in the direction of the desired stiffness with the object represents the magnitude of the stiffness in that direction (e.g., the figure illustrates the stiffness values for the 2-direction).







$$C_{com} = \frac{E_H(1-\nu_{HV}\nu_{VH})}{(1+\nu_H)(1-\nu_h-\nu_{hv}\nu_{vh})}$$

$$C_{s,max,min} = G_v$$

This visualization technique a) quantifies the stiffness matrix made up of 36 constants, b) results in compressive and shear stiffness, which can be interpreted for any direction, c) allows one to quickly see where the softest soil response is, and d) can be used to understand the evolution of stiffness and stress –strain relationship for a given loading, thus allowing an immediate interpretation of the modeled soil behavior for complex non-linear constitutive models used in the solution of boundary value problems.